RESEARCH DEPARTMENT

SOME ASPECTS OF VESTIGIAL-SIDEBAND TRANSMISSION OF COLOUR TELEVISION WITH ENVELOPE DETECTION

Report No. T-094

(1962/29)

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

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G.F. Newell, A.M.I.E.E.

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SUMMARY

This report shows that the assessment of the merits of a colour television system in fulfilling the principle of constant luminance must take into account the errors that can result from the use of a vestigial-sideband emission with envelope detection. Comparison is made between the NTSC system and the modified form of this proposed by James and Karwowski. As regards the reproduction of colour in large areas, the NTSC system is in some respects superior to the James and Karwowski system.

1. INTRODUCTION

The recovery of the video modulation from a television transmission is normally achieved by the use of an envelope detector in the receiver. This detector produces an output waveform proportional to the envelope of the input modulated carrier. Conventional forms of this circuit employing either valve or crystal diodes are almost perfectly adequate for the recovery of the modulation of a signal if only one parameter of the signal, the amplitude, is varied by the modulation. This condition can be met if the input to the detector is a double-sideband amplitude-modulated signal, but, if the upper and lower sideband amplitudes are unequal, or if an interfering carrier is added, the resultant signal will vary in phase from that of the original carrier. In these conditions the envelope of the resultant signal will not represent the original modulation, and neither will the detector output.

The limitations of asymmetric-sideband reception using an envelope detector have been fully dealt with by Cherry,[1] and in this report we consider only two aspects which affect the accuracy of the reproduction of the chromaticity of large areas of colour in television pictures. Consider the representation of a double-sideband amplitude-modulated signal shown in Fig. 1(a) and the output of an envelope detector 1(b). If one sideband is removed from the signal as depicted in Fig. 1(c), the output of the detector is as represented in 1(d). The removal of one sideband has reduced the sideband power by 3 dB but the amplitude of the modulation component has dropped by 6 dB. It is interesting to note that the mean level of the detector output has increased as a result of removing one sideband. It can be shown that this increase represents an amount of power slightly greater than that contained in the "a.c. component" of the detector output. In fact, slightly more than half the sideband power radiated in a single-sideband transmission received with an envelope detector, is converted into an increase of the mean, or "d.c. component" of the signal.

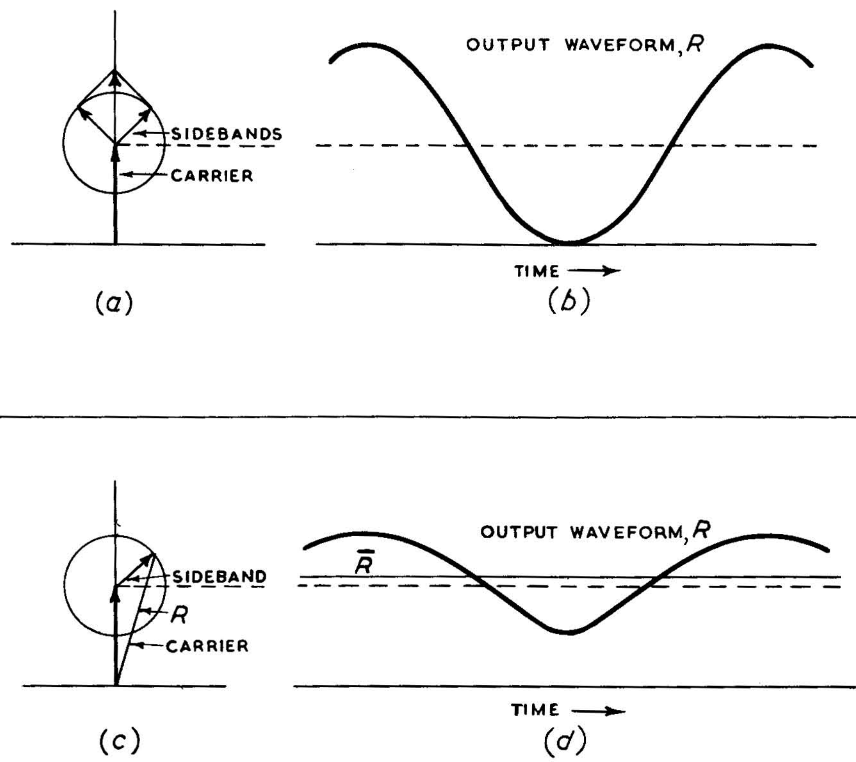

Fig. 1 - Single-and double-sideband detection

(a) and (b) Double sideband signal $R = (1 + C^2 + 2C \cos\theta)^{\frac{1}{2}}$

(c) and (d) Single sideband signal $\bar{R}^2 \doteq 1 + C^2/2$

2. LUMINANCE AND CHROMINANCE ERRORS

The vestigial-sideband transmission of the type of colour-television systems in which we are interested can be considered as single-sideband as regards the colour information, see Fig. 2. If a transmitted colour picture has a large area of uniform colour, the signal representing this area can be considered as consisting of a carrier, $\cos \omega t$, containing the luminance and synchronizing components, and a sideband $C \cos (\omega + p)t$ containing the colour component. The combination of these two cosine waves can be expressed as a function of time, $f(t)$.

$$f(t) = R \cos (\omega t + \Phi) \tag{1}$$

$$\text{where } R = (1 + C^2 + 2C \cos \theta)^{\frac{1}{2}},$$

$$\text{and } \theta = pt$$

$$\text{and } \tan \Phi = (C \sin \theta)/(1 + C \cos \theta).$$

If $f(t)$ is the input to an envelope detector, the output waveform will be proportional to R. A solution for R in the form of a series has been given by Colebrook.[2]

$$R = a_0 + a_1 \cos \theta - a_2 \cos 2\theta + \ldots (2)$$

We need consider only the first two terms because the harmonics of the colour component will not be passed through the video circuits. The value of a_0 is plotted in Fig. 3 as a function of the sideband amplitude C. Fig. 4 shows the reduction of the colour component as a percentage, that is $100(C - a_1)/C$, as a function of C.

The power contained in the mean or "d.c. component" is

$$\bar{R}^2 = a_0^2 \simeq 1 + C^2/2 \text{ when } C \text{ is small}$$

but when C is equal to the amplitude of the carrier, i.e. $C = 1$ in equation (1),

$$\bar{R}^2 = 1 + 0{\cdot}62\ C^2$$

From this we see that more than half the power contained in the colour signal is converted into an increase of the mean level. In addition to this loss of power a further decrease of the colour signal results from the power lost in harmonic distortion terms, but these are not large. The mean value of Φ is zero and there is no error in the hue of the colour. If the system uses positive modulation, the increase of the mean component represents an increase of luminance, but if negative modulation is employed, a reduction of luminance results. If the system is of the so-called constant-luminance variety as in the case of that proposed by James and Karwowski,[3] the reduction of the colour signal amplitude results in a small change of saturation. In the case of the NTSC

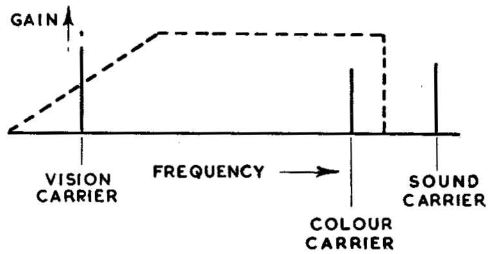

Fig. 2 - Vision receiver amplitude/frequency response

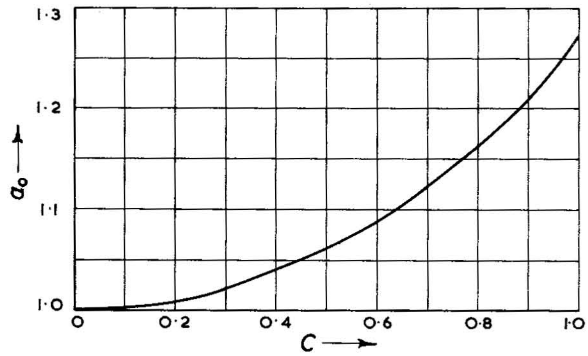

Fig. 3 - Mean value of demodulated signal resultant

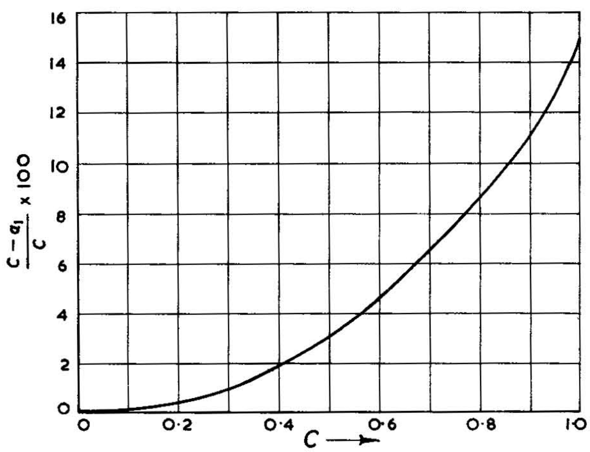

Fig. 4 - Fundamental harmonic component of detected colour carrier

system which does not completely fulfil the constant-luminance principle the colour signal contains some of the luminance component. If the modulation has positive polarity, the reduction of the chrominance signal amplitude causes a decrease of luminance which can partly compensate for the increase caused by the increase of the mean component. If negative modulation is employed, both effects produce a decrease of luminance. The luminance errors for a number of colours, including most of those proposed as test colours by Sproson,[4] and the saturated primaries, red, green and blue, were computed for the NTSC system and for that proposed by James and Karwowski. These errors, shown in Table 1 for both positive and negative modulation, are expressed in just noticeable differences (j.n.d's), one j.n.d. being a 3% luminance change.* For positive modulation the luminance signal was assumed to be confined between the limits of 35% of carrier amplitude (black) and 100% (white). For negative modulation the limits were taken as 75% (black) and 10% (white) of the carrier amplitude.

Examination shows that the constant-luminance system offers no marked superiority. In fact, with positive modulation, the NTSC system is superior for

TABLE 1

LUMINANCE ERRORS IN 'JUST NOTICEABLE DIFFERENCES' IN COLOUR RECEIVERS

COLOUR	POSITIVE MODULATION		NEGATIVE MODULATION	
	NTSC	CONSTANT-LUMINANCE SYSTEM (JAMES AND KARWOWSKI)	NTSC	CONSTANT-LUMINANCE SYSTEM (JAMES AND KARWOWSKI)
1 RED (Rotaprint)	2·2	1·9	3	2·5
2 ORANGE (Ilford)	4·1	3·2	5	5·5
3 YELLOW (Kodak)	1·6	1·9	9	7
4 GREEN (Dreft)	1	1·3	2	2·5
5 BLUE-GREEN	1	1·3	2	2
6 BLUE	0·7	11·6	1·5	1
7 BRIGHT RED	2·5	1·9	3·5	3·5
8 DARK RED	2·2	1·9	2	1
9				
10 YELLOW	2·5	2·2	6	7
11 LIME-GREEN	1·3	1	1·5	2·5
12 GREEN	2·5	2·9	2·5	6
13 DARK BLUE	2·5	2·5	2	1·5
14 RED (Saturated)	6	7	13	13
15 GREEN (Saturated)	4	11	17	10
16 BLUE (Saturated)	2.5	11	10	14

*The value of 3% was chosen as a compromise between the more generally accepted figure of 2% and that of 4·5% measured by Brown and MacAdam.[9] To correct the errors in Table 1 to 2% j.n.d's multiply by 1·5; to obtain the errors in terms of 4·5% j.n.d's multiply by 0·67.

the saturated colours. The computations were based on the assumption that, for the constant-luminance system, the receiver used was of the "ideal" variety proposed for use with this system.

The problems of transmitting the NTSC waveform with negative modulation have been discussed by Fredendall.[5] The reception problems can be considerably reduced by the use of the "exalted carrier"[6] technique in the receiver. This requires that the i.f. amplifier be designed to produce a much higher gain at the vision-carrier frequency than at the sideband frequencies. The result is that the input to the envelope detector has a much smaller depth of modulation than would be the case with a conventional i.f. amplifier. As is shown by Figs. 3 and 4, the reduction of the relative amplitude of the chrominance sidebands at the detector input results in a reduction of the effects discussed. The video-frequency amplifier must be designed to have a non-uniform gain over the frequency band in order to equalize the overall response. It is interesting to note, however, that receivers designed for the reception of the 405-line, positive-modulation, experimental colour emissions in the United Kingdom employ i.f. amplifiers identical with those used for domestic monochrome reception except for a little extra preservation of the gain uniformity over the chrominance signal frequencies. In fact, lack of constant luminance in large areas, was not one of the criticisms remarked upon during the colour trials in this country.

3. RECEPTION OF COLOUR EMISSIONS BY MONOCHROME RECEIVERS

Although receivers intended for colour reception can be specially designed for the system used, it is important to consider the effect of the colour emissions on monochrome reception. This is important because large numbers of monochrome receivers may be in use before the colour emissions commence.

The tonal range of the grey scale reproduced by monochrome reception of colour emissions is not the same as the luminance range produced by colour receivers. The chrominance signal is passed by the video amplifier of the monochrome receiver and appears as a dot pattern in the displayed picture. As was shown by Maurice,[7] the non-linear relationship between the c.r.t. drive voltage and the displayed brightness partly rectifies the chrominance signal, and alters the mean brightness of areas containing colour in the transmitted picture.

Table 2 shows the computed brightness errors for monochrome reception of the same colours considered for the colour receiver. The c.r.t. brightness/voltage characteristic was assumed to be:

$$B = v^{\gamma} + B_0$$

where B = the reproduced brightness

v = the c.r.t. drive voltage

$\gamma = 2{\cdot}5$

B_0 = the brightness reflected from the c.r.t. screen by the ambient illumination of the room containing the receiver.

TABLE 2

PERCENTAGE BRIGHTNESS ERRORS FOR MONOCHROME RECEIVERS

COLOUR	POSITIVE MODULATION		NEGATIVE MODULATION	
	NTSC	CONSTANT-LUMINANCE EMISSION (JAMES AND KARWOWSKI)	NTSC	CONSTANT-LUMINANCE EMISSION (JAMES AND KARWOWSKI)
	%	%	%	%
1 RED (Rotaprint)	-17·9	21·0	-31·2	6·0
2 ORANGE (Ilford)	- 5·6	33·3	- 2·8	6·0
3 YELLOW (Kodak)	4·5	19·2	-29·6	-22·0
4 GREEN (Dreft)	-13·7	15·0	-17·4	0
5 BLUE-GREEN	-18·4	16·8	-25·8	4·0
6 BLUE	-17·6	15·0	-24·8	4·8
7 BRIGHT RED	-18·8	25·2	-94·8	7·0
8 DARK RED	-41·8	24·9	-45·6	14·4
9				
10 YELLOW	2·2	24·0	-25·9	-12·0
11 LIME-GREEN	- 6·4	8·0	-16·6	- 4·0
12 GREEN	-22·8	45·0	-33·7	10·8
13 DARK BLUE	-51·1	27·0	-53·3	13·8
14 RED (Saturated)	2·6	52·5	-53·2	2·5
15 GREEN (Saturated)	- 2·6	131·1	-54·3	-89·7
16 BLUE (Saturated)	-23·3	136·4	-60·3	102·0

The ambient reflected light, B_0, was assumed to be one-fortieth of the peak-white brightness. The computed errors include those caused by the envelope detection of the v.s.b. signal and those caused by the c.r.t. non-linearity. The errors are shown as percentages of the correct brightness of the transmitted colours. This method of showing the errors was chosen in preference to the "just noticeable difference" method because the latter does not indicate whether the error is in the form of increased or decreased brightness. The panchromatic reproduction is likely to be more seriously marred if large brightness errors are in opposite sense for various colours.

Table 2 shows that with negative modulation the constant-luminance system is superior except for saturated green and blue, but it must be remembered that saturated green does not occur frequently in nature. For positive modulation the NTSC system is not inferior to the constant-luminance system and is in fact superior for the saturated colours.

It is interesting to note that during the compatibility trials[8] of the NTSC system as adapted for the 405-line positive-modulation system the grey scale reproduction was not criticised.

4. CONCLUSIONS

The computed errors of luminance for colour reception, and brightness for monochrome reception show that the distortion introduced by v.s.b. reception using an envelope detector nullifies some of the advantages of the constant-luminance system proposed by James and Karwowski. Colour receivers can be designed to minimise the effects of envelope detection and in these conditions the constant-luminance system would be superior. If positive modulation is used the NTSC system possesses good constant-luminance qualities if the receiver has an i.f. amplifier with the conventional gain/frequency characteristic.

Reception of negative-modulation colour emissions with monochrome receivers would result in good grey scale reproduction except for some saturated colours if the constant-luminance system were employed. With positive modulation, however, the NTSC system is likely to prove superior.

It has been shown that assessment of the constant-luminance qualities of a colour television system must take account of the effects of vestigial sideband transmission with envelope detection.

5. ACKNOWLEDGEMENTS

The author wishes to acknowledge the help of his colleague D. Howorth who carried out the computations involved in the two tables.

N.B. This report was read as a paper to a meeting of the Brit.I.R.E. held in December 1961.

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Printed by B.B.C. Research Department, Kingswood Warren, Tadworth, Surrey